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CLIMATIC CHANGE AND ITS IMPLICATIONS FOR THE AMPHIBIAN FAUNA

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Summary

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The dependence of frogs upon moisture makes them highly sensitive to environmental conditions. The South Australian frog fauna includes 28 species which collectively and individually experiences a wide temporal range of temperature and available moisture. Any climatic change involving warmer and moister conditions is likely to enhance their distribution and abundance.

KEY WORDS: Frogs, moisture, distribution, South Australia.

Introduction

The relevance of the study of frogs in any evaluation of the impacts of climatic change hinges upon recognition of the dependence of these animals upon moisture. Nevertheless the survival of frogs throughout the period that witnessed the entire evolution of all other terrestrial vertebrates, demonstrates the capacity of frogs to survive massive environmental changes.

The complete extent of the diversity of the modern frog fauna is unknown: Duellman (1993) estimates a total of 3967 species at 31.xii.91, and numerous species have been described subsequently. In Australia the current total is 203, but many more await description.

Despite the success and longevity of frogs as an evolutionary lineage they remain dependent upon moisture because of the relative permeability of the skin and (in most species) the need to deposit eggs in free bodies of water.

It follows that frogs are highly sensitive indicators of environmental pollution and, equally, that they contribute an early warning system in terms of detecting environmental changes.

Any climatic change in South Australia at a regional or total level is likely to impact upon the distribution of species, and upon the number within this State.

South Australian frog fauna

Currently 28 species of frogs have been reported from South Australia. The largest number of species in any area (11) is to be found in the lower southeast which is also the area of highest rainfall. However comparable numbers are found in the arid northwest (9) and northeast (10) (Table 1).

The northwest and the northeast are also the portions of South Australia where numerically and proportionately there are the most species not shared with other areas (Table 1). In each instance these "unique" species are known within South Australia from fewer than six localities, and each species is more widely distributed outside the State. Numerous frog species in South Australia are at the geographic limit of their distribution, and climatic change may have a dramatic influence upon their persistence or abundance.

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TABLE 1: *Geographic characteristics of South Australian frog fauna.*

Geographic Area	Number of species	Species confined to that area	Known from less than six localities
Northwest	9	5	5
Northeast	10	5	5
Flinders Ranges	5	1	0
Eyre Peninsula	3	0	0
Yorke Peninsula	2	0	0
Mt Lofty Ranges	7	0	0
Murray Valley	9	3	0
Kangaroo Island	6	0	0
Lower southeast	11	4	0
Nullarbor Plain	2	0	0

Impact of Rainfall

Although the amount of rainfall and its reliability are not the only factors influencing frog distribution, the generality can be made that the persistence of moisture at or near ground level is most important.

To predict faunal impact in South Australia it is pertinent to examine a geographic area in which there is a progressive increase or decrease in rainfall along a latitudinal gradient. The one area in Australia in which this requirement is met is the Northern Territory, where there is a progressive reduction in annual rainfall from north to south (Fig. 1).

The Northern Territory model

Based upon the distribution patterns of the 42 species then known from the Northern Territory plotted by

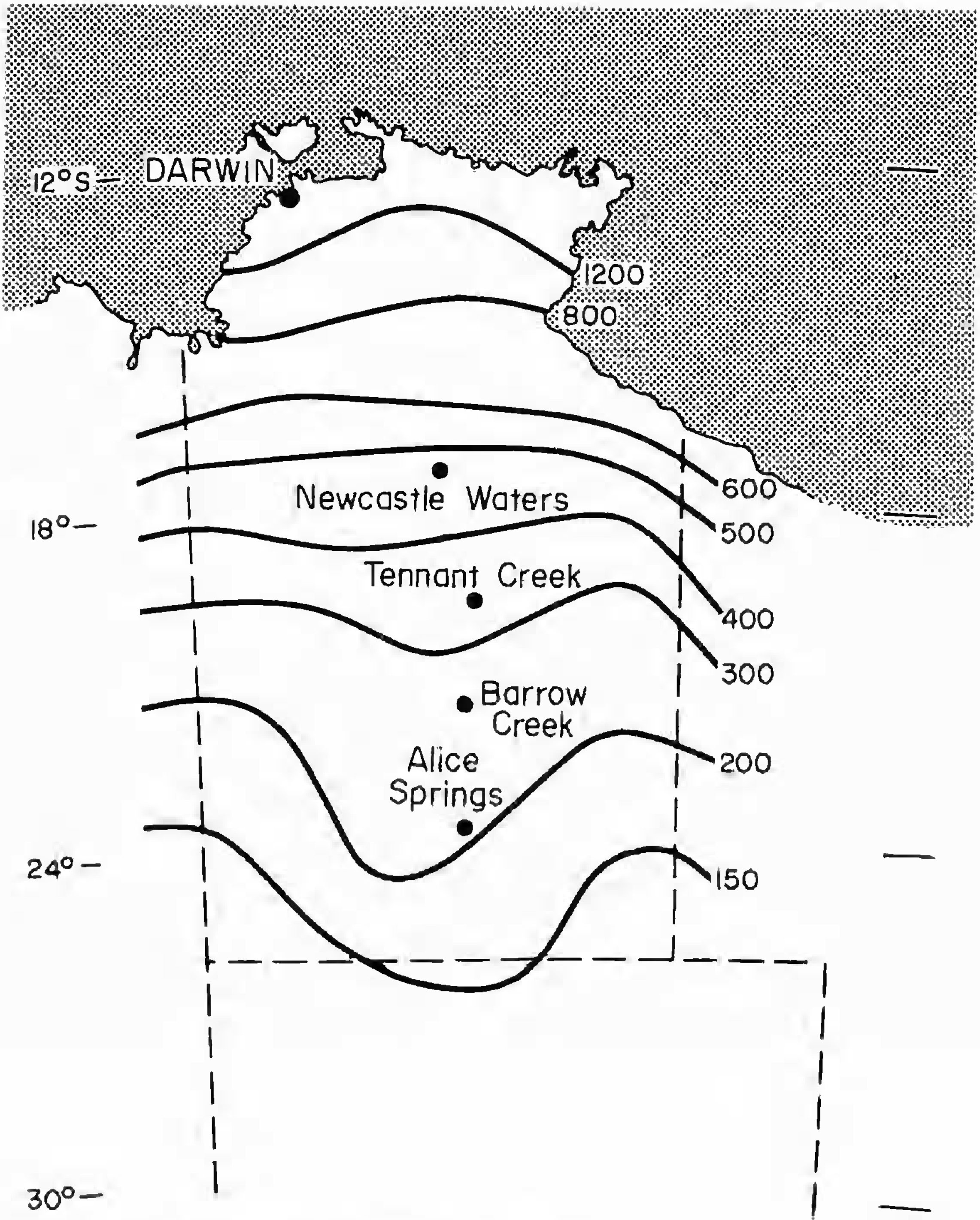

Fig. 1. Northern Territory showing latitudes, isohyets and major centres.

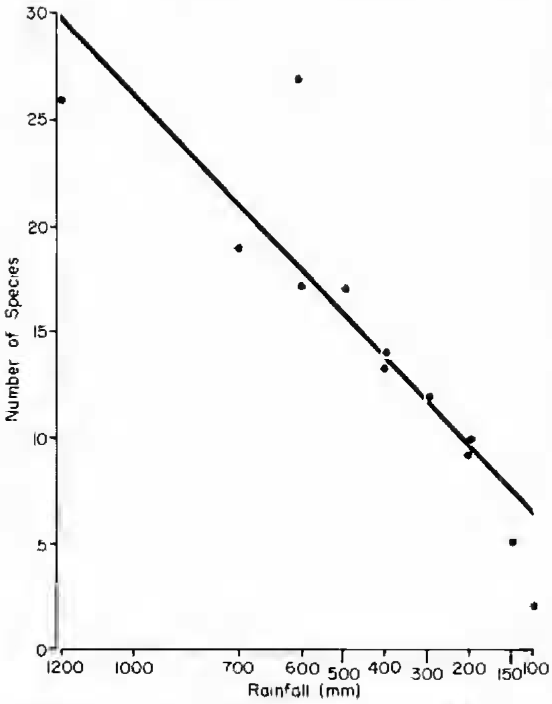

Fig. 2 Number of species plotted against isohyets (r = .750).

Tyler & Davies (1986) there is a distinct association between rainfall and the number of species (Fig. 2) within rainfall zones where there is 100-500 mm per annum. At rainfalls higher than 500 mm the trend is not apparent, but the geographic area involves Arnhem Land which has been largely inaccessible to collectors. I anticipate that the totals for the more northern latitudes will increase when zoological exploration becomes possible.

Because of their dependence upon having access to sources of moisture, the evolutionary capacity of body size and mass of frogs are closely linked to the reliability of sources of moisture. Species of small size have a surface area to mass relationship that is fitted to reliable sources of moisture. Conversely the capacity to withstand xeric conditions requires that the surface area from which water is lost is, by some means, reduced. Effectively large, bulky frogs are best equipped for xeric conditions.

Although the length of the body bears no fixed relationship to body mass, it is the standard expression of size (S-V = snout to vent length). In Australian species there is marked sexual dimorphism : males are always smaller than females (except for the eastern Australian species *Adelotus brevis*). To examine any geographic trends in size I have used a median

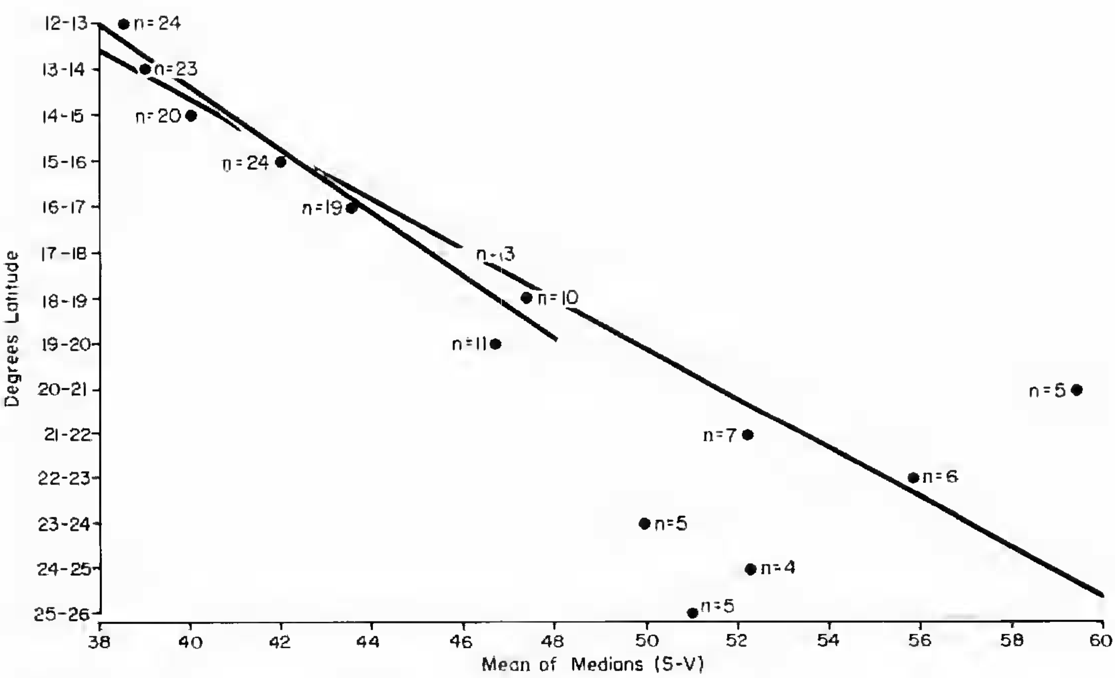

Fig. 3. Number of species occurring within particular latitudes (boundaries at single degree positions) plotted against mean of medians of snout to vent length (S-V). Two linear regression lines have been plotted: one between 12° and 20°S (r = .948), the second between 12° and 26°S (r = .975).

measurement, being the midpoint between the size of the smallest adult male and largest adult female. The first of these analyses followed the standard 1° latitudinal divisions (Fig. 3). The second involved similar latitudinal divisions but separated at the intermediate 0.5° divisions (Fig. 4). Essentially the results are similar: small species are associated with high levels of moisture, and in arid areas larger species predominate.

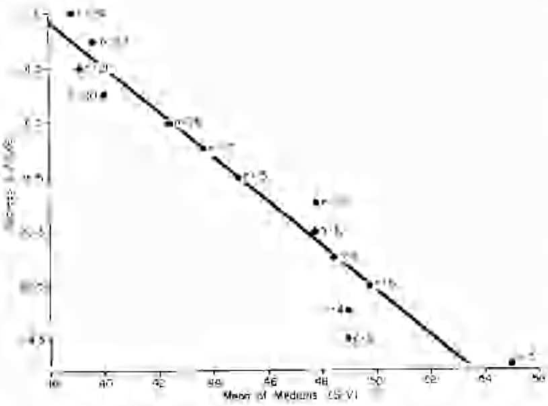

Fig. 4. Number of species occurring within particular latitudes (boundaries at half degree positions) plotted against medians of snout to vent length (S-V). Regression line r = .921.

The overall lifestyle of frogs also is reflected along these north-south transects of decreasing available moisture. In terms of the size of the individuals there is a shift in the predominance of small species to larger ones associated with rainfall. Equally there is a distinct change in the overall lifestyle of these same species, such that the terrestrial/aquatic mode shifts from more than 50% in the extreme north of the Northern Territory to zero at 21° latitude south.

Existing geographic trends in South Australia

Within South Australia there is a direct association between the number (and diversity) of species and geographic area, but without the latitudinal decrease from the arid north to the moist south. Instead there are pockets of species, each of which has its own unique features.

For example any gradient is destroyed by the presence of a wet refuge like that of the Coongie Lakes system in the northeast of this State — an intrusion of an area wholly atypical within a broad zone of low and irregular rainfall. The Coongie Lakes frog fauna is particularly rich, but not permanent because of the period of drought. It has been suggested that the northeast of the State presents a dynamic situation in which there is contraction and expansion of populations according to the availability of moisture and repeated transportation of species from southern Queensland (Tyler 1990: Fig. 3).

The River Murray presents a further dimension because it constitutes a route for the introduction of species from the east. *Litoria peroni* and *Crinia parinsignifera* enter the State by this means, and are confined to its vicinity.

The toadlet *Pseudophryne occidentalis* has an extensive distribution in Western Australia, whereas in South Australia it has been found only at Victory Well in the Everard Ranges in the northwest. The existence of species within such restricted areas is of significance to palaeoclimatic interpretation. Because of the small geographic area to which it is confined, the dependance of the species upon moisture, and the existence of more arid conditions around the area, it can be inferred that since the time of dispersal to that site, it has not been more arid there than at present.

With the exception of *Crinia riparia* which is wholly confined to the Flinders Ranges, every species in South Australia has a more extensive distribution beyond the State boundaries. In fact the percentage of endemism in South Australia is less than in any other Australian State.

The implications of climatic change

The climatic variables that influence the geographic distribution of Australian species of frogs are very poorly known. Brattstrom (1970) was the first to demonstrate an association in montane species between altitudinal location and tolerance to temperature fluctuations. In particular he indicated that the species occupying the cooler habitats had the least capacity to adapt to a change in thermal regime.

Unfortunately the climatic variables that have particular influence upon the spatial distribution of frogs are, at best, inferred rather than demonstrated. For example, what is the limiting factor of the distribution of the tree frog *Litoria rubella* which extends as far south as Wilpena Creek in the Flinders Ranges?

This species ranges across the entire northern half of the continent, principally within the area of summer rains (Fig. 5). A commensal species, it is clearly capable of adapting to changing environments. It can be assumed that a climatic change producing warmer and moister conditions will enhance the geographic range of *L. rubella*.

Perhaps the most significant influence of climatic change will be the creation of more aquatic breeding sites and the persistence of these sites for longer periods. Together these factors will modify habitats in a manner that is advantageous to frogs. Hence the Coongie Lakes are likely to become more persistent, and the fauna there more stable in a temporal sense than at present.

Fig. 5. Geographic distribution of *Litoria rubella*

Conclusion

Any climatic change that results in a moister and warmer climate in South Australia is likely to enhance the geographic distribution of the constituent species. This can be assumed because of the wide range of temperatures experienced already by South Australian species, and the fact that a warmer and moist regime will ameliorate the existing seasonally harsh environmental conditions.

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